LATEST DEVELOPMENTS IN NWC SAF HIGH RESOLUTION WINDS PRODUCT

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Abstract

The "High Resolution Winds product (HRW)", developed inside the "Satellite Application Facility on support to Nowcasting and very short range forecasting (NWC SAF)" software package, provides a detailed calculation of Atmospheric Motion Vectors locally and in near real time. Several important changes have been implemented in its algorithm in the last two years, up to current HRW v2012 version.

The AMVs extraction capabilities have been extended, tuned and validated for seven SEVIRI channels (HRVIS, VIS06, VIS08, WV062, WV073, IR108, IR120), considering both Cloudy AMVs and Clear air Water Vapour AMVs. "CCC method" proposed by Borde and Oyama (2008) has been implemented in the algorithm for the AMV height assignment, using NWC SAF/Cloud Top Temperature and Height product data. The results of the last version validation, showing significant improvements through smaller RMSVDs, are shown in this paper.

Preliminary results of a study that aims to better understand the temporal and spatial scaling issues associated to the AMV extraction are also shown. In the framework of this study, HRW v2012 AMVs have been extracted from MSG-1 Rapid scan HRVIS and VIS08 channel data. Results are studied for different target sizes (8x8 to 40x40 pixels) and temporal gaps between images (5 to 90 minutes). The outputs have been validated against Radiosounding winds and NWP analysis wind fields.

NWC SAF/HIGH RESOLUTION WINDS PRODUCT NEW VERSION (HRW v2012)

The "High Resolution Winds (HRW)" is the Atmospheric Motion Vector (AMV) product included inside the "Satellite Application Facility on support to Nowcasting and Very short range forecasting (NWC SAF)" Software package for Geostationary satellites (SAFNWC/MSG). It provides high density sets of AMVs from MSG/SEVIRI images for near real time applications (see Figure 1 and Figure 2).

Two important changes have been developed between 2010 and 2012 up to version HRW v3.2 (v2012), released to users in March 2012:

- The extension of the AMV calculation with up to seven MSG/SEVIRI channels: HRVIS, VIS06, VIS08, IR108, IR120, WV062, WV073.
- A new Height assignment procedure using "CCC Method" (Borde & Oyama, 2008, [RD.4]).

With these changes, the density of AMV data increases significantly, the holes in the coverage reduce significantly and Clear air AMVs are calculated for the first time (with WV062 and WV073 channels). Additionally, using "CCC Method" for the Height assignment, the AMV pressure is defined considering only the pressure of the pixels contributing most to the image correlation, and "NWC SAF/Cloud products (Cloud mask, Cloud type, Cloud top temperature and height)" are processed inside HRW algorithm as cloud information input, including so their techniques to set the "Cloud height":

- Opaque cloud top pressure retrieval from IR108 and IR120 brightness temperatures through RTTOV simulation of radiances, including the possibility of thermal inversion processing.
- Semitransparent cloud top pressure retrieval with the "Radiance ratioing method" (by Menzel et al. 1983) and "Water vapour/Infrared window intercept method" (by Schmetz et al. 1993) using WV062, WV073 and IR134 as sounder channels.

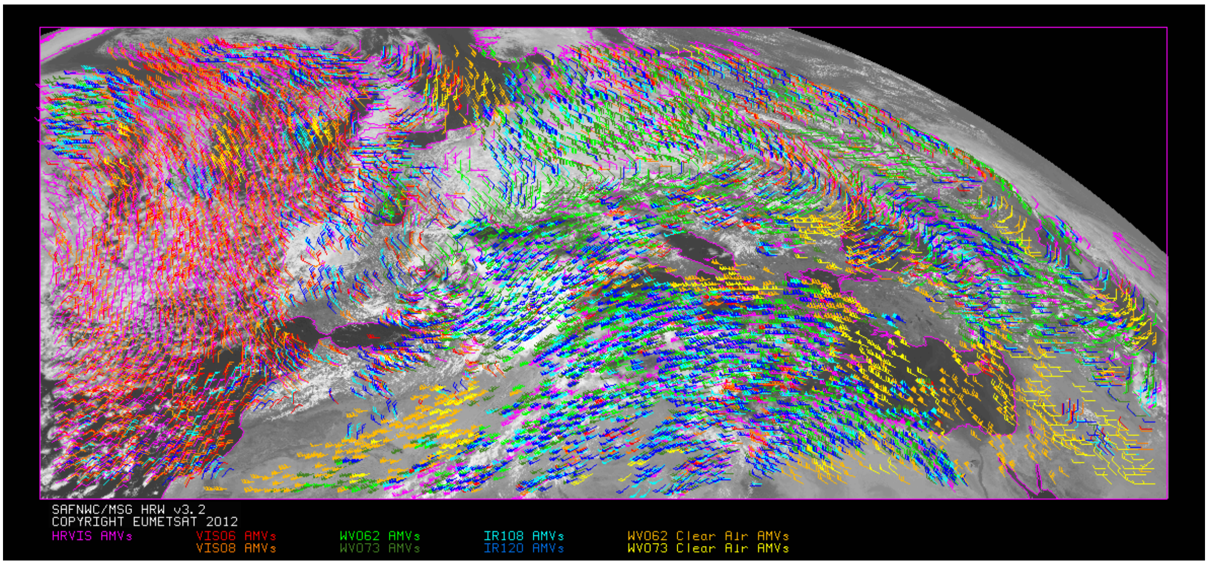


Figure 1: **Example of NWC SAF/High Resolution Winds v2012 output for 14 May 2010 at 1200Z, with colour coding based on the MSG/SEVIRI channel used for the AMV calculation.**

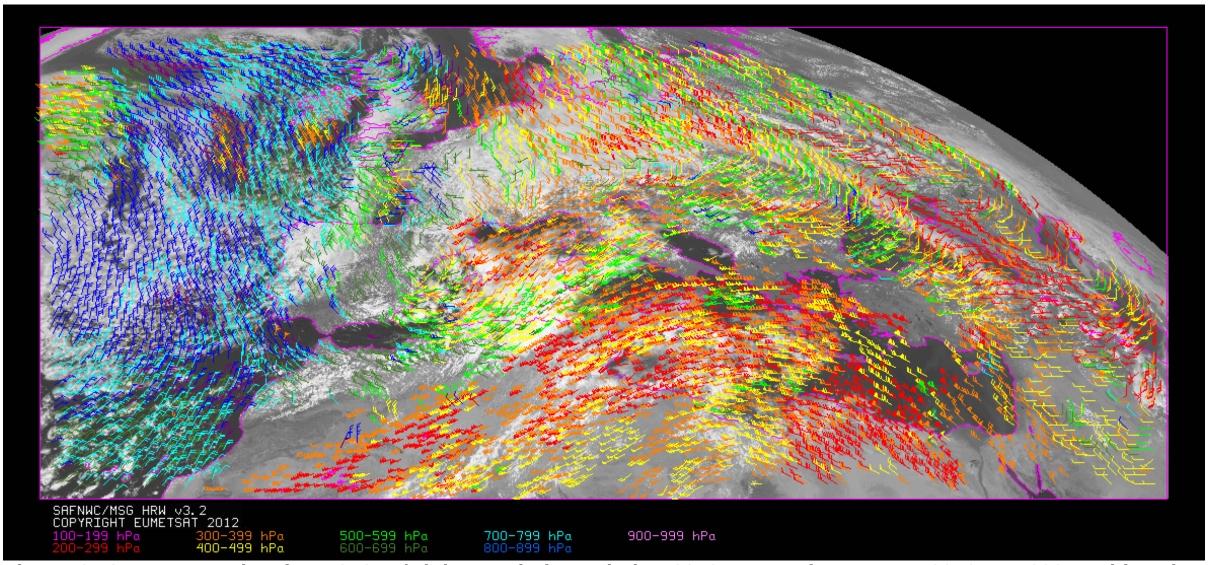


Figure 2: **Same example of NWC SAF/High Resolution Winds v2012 output for 14 May 2010 at 1200Z, with colour coding based on the AMV pressure level.**

The specific conditions for the implementation of “CCC Method” in NWC SAF/High Resolution Winds algorithm for Cloudy AMVs are the next ones:

- Only the cloudy pixels (as defined by “NWC SAF/Cloud type product” output) are used by “CCC method” for the “AMV pressure” and “AMV pressure error” calculation, for which the “cloud top pressure output” from “NWC SAF/Cloud Top Temperature and Height product” is used.
- Only the bright branch of the “Reflectance(Pixel correlation contribution) graph” is used in the process with the visible channels (HRVIS, VIS06, VIS08), and only the largest branch of the “Brightness temperature(Pixel correlation contribution) graph” is used with the infrared and water vapour channels (IR108, IR120, WV062, WV073), as shown in Figure 3.

The modifications defined for the use of “CCC method” with Water Vapour (WV062, WV073) Clear air AMVs are:

- The “AMV temperature” and “AMV temperature error” are calculated instead, considering the Water vapour channel brightness temperature and the cold branch of the “Brightness temperature(Pixel correlation contribution) graph”.
- The “AMV pressure” is then calculated interpolating the “AMV temperature” to the NWP temperature forecast profile.

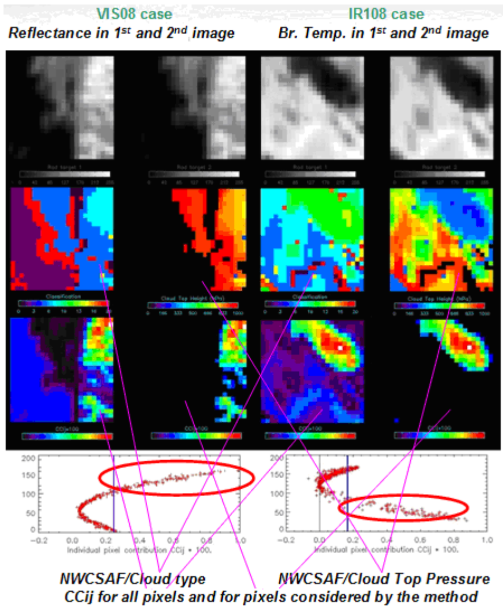


Figure 3: **Elements for the "AMV pressure calculation" with "CCC method", for two Cloudy VIS08 (left) and IR108 (right) cases. In the first row, the "Visible Reflectances" and "Infrared brightness temperatures" are shown for the initial and final position of the tracer in the initial and final images. In the second row, the "NWC SAF/Cloud type" and "NWC SAF/Cloud top pressure" outputs for the final positions of the tracer are shown. In the third row, the "Pixel correlation contribution" for the final positions of the tracer, considering all pixels (left) and only the pixels over the CCC method calculation threshold (right), is shown. In the lower row, the "Reflectance(Pixel correlation contribution)" and the "Brightness temperature(Pixel correlation contribution)" graphs are shown, with the "CCC method calculation threshold" drawn as a vertical blue line.**

NWC SAF/HIGH RESOLUTION WINDS v2012 VALIDATION

Comparing the Validation statistics against Radiosounding winds for versions HRW v2010 and v2012 (for the reference yearly period July 2009-June 2010 in the "Europe and Mediterranean Region" shown in Figures 1 and 2), there has been an important increase in the amount of AMV data (not only because of using more MSG/SEVIRI channels, but also considering only the statistics related to HRVIS and IR108, for which AMVs were also calculated with HRW v2010), with an important reduction of the NMVD and NRMSVD (around a 20%), although also with an increase in the NBIAS.

HRW v3.0 AMV Validation (Jul 2009-Jun 2010)	cloudy HRVIS			cloudy IR108						all AMVs
NC	53915			47941						101856
SPD [m/s]	15.03			17.01						15.96
NBIAS (ALL LAYERS)	-0.04			-0.03						-0.04
NMVD (100-1000 hPa)	0.38			0.40						0.39
NRMSVD	0.48			0.49						0.48

HRW v3.2 AMV Validation (Jul 2009-Jun 2010)	cloudy HRVIS	cloudy VIS06	cloudy VIS08	cloudy IR108	cloudy IR120	cloudy WV062	cloudy WV073	clear air WV062	clear air WV073	all AMVs
NC	138633	71213	64022	112833	115171	133011	176648	34023	14155	859709
SPD [m/s]	18.03	11.75	11.71	19.68	19.89	23.63	21.96	17.46	13.58	19.08
NBIAS (ALL LAYERS)	-0.11	-0.16	-0.16	-0.11	-0.10	-0.06	-0.08	-0.05	-0.02	-0.08
NMVD (100-1000 hPa)	0.32	0.44	0.44	0.32	0.32	0.29	0.31	0.34	0.39	0.33
NRMSVD	0.40	0.52	0.52	0.41	0.40	0.36	0.39	0.42	0.46	0.41

Figures 4 and 5: **Validation statistics against Radiosounding winds for NWC SAF/High Resolution Winds v2010 (up) and v2012 (below) in the "European and Mediterranean Region" for the year July 2009-June 2010, considering all atmospheric layers together (100-1000 hPa). (NC: Number of collocations; SPD: Mean radiosounding speed in m/s; NBIAS: Normalized bias; NMVD: Normalized mean vector difference; NRMSVD: Normalized root mean square vector difference).**

Some filterings have been defined inside HRW v2012 AMV output, related to the variation of the NRMSVD with the AMV Cloud type and the MSG/SEVIRI channel:

- HRVIS AMVs are valid for all cloudy types except "High semitransparent thin clouds" & "High semitransparent clouds above other clouds".
- VIS06 and VIS08 AMVs are only valid for "Very low to medium clouds".
- IR108 and IR120 AMVs are valid for all cloudy types except "High & very high opaque clouds".
- WV062 AMVs are valid for all types except "Very low to medium clouds".
- WV073 AMVs are valid for all types.

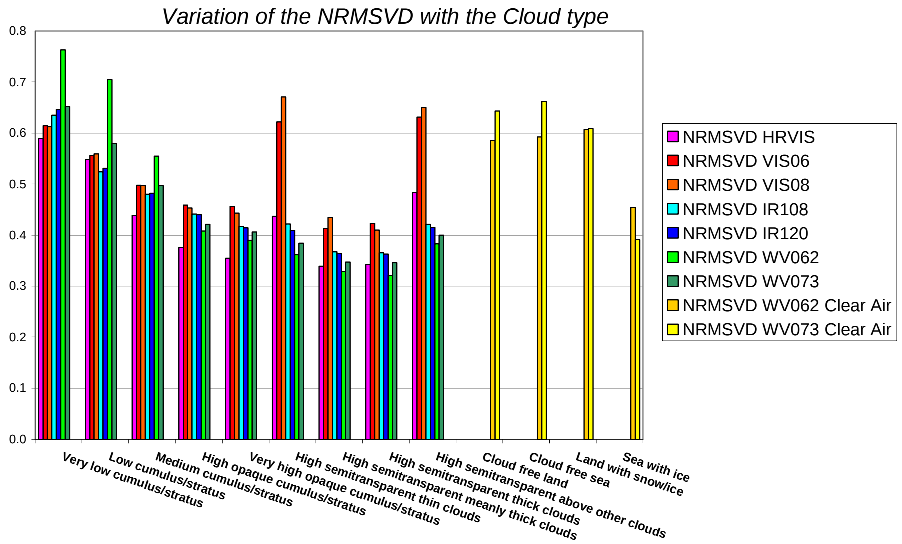


Figure 6: **Variation of the NRMSVD (Normalized root mean square vector difference) with the AMV Cloud type and the MSG/SEVIRI channel used for the AMV calculation.**

Verifying the variations of the NBIAS and NRMSVD with the pressure level and the MSG/SEVIRI channel used for the AMV calculation:

- Few differences are found in the NRMSVD respect to the pressure level in the AMVs related to different channels. Only HRVIS AMVs show clearly smaller values in the medium layer and WV062 Clear air AMVs show larger values.
- The NBIAS in Cloudy AMVs is progressively more negative in Water vapour, Infrared, High resolution visible and Low resolution visible AMVs.
- The NBIAS in Clear air AMVs is more negative at lower levels and larger for WV062 AMVs.

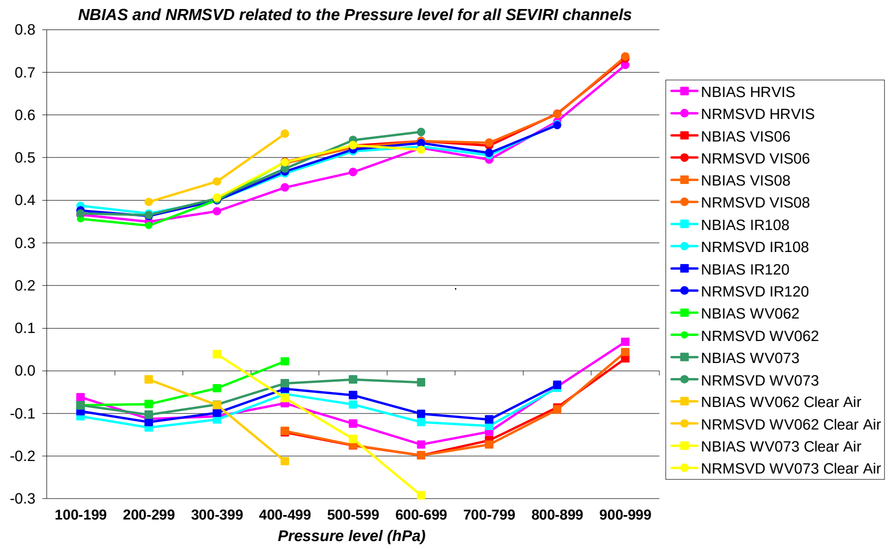


Figure 7: **Variation of the NBIAS (Normalized bias) and NRMSVD (Normalized root mean square vector difference) with the Pressure level and the MSG/SEVIRI channel used for the AMV calculation.**

NWP ASSIMILATION STUDIES WITH NWC SAF/HIGH RESOLUTION WINDS

An NWP Assimilation study has been evaluated by Roger Randriamampianina (from the Hungarian Meteorological Service, OMSZ), comparing the impact of NWC SAF/HRW AMVs with those produced at EUMETSAT/MPEF. This study has been taken considering the OMSZ Hydrostatic ALADIN CY36T1 limited area NWP model, with 3DVAR Upper air assimilation analysis, Optimum interpolation surface analysis and Digital filter initialization technique, during one month of the Summer 2011.

For this study the AMV output from HRW v2011 has been used, considering HRVIS AMVs by day and IR108 AMVs by night. The relative impact in the NWP analysis of the AMV data (for both MPEF and HRW AMVs) is very important, although the absolute impact is small (because of the small amount of active AMV observations, a number being in the tens for both HRW and MPEF AMVs).

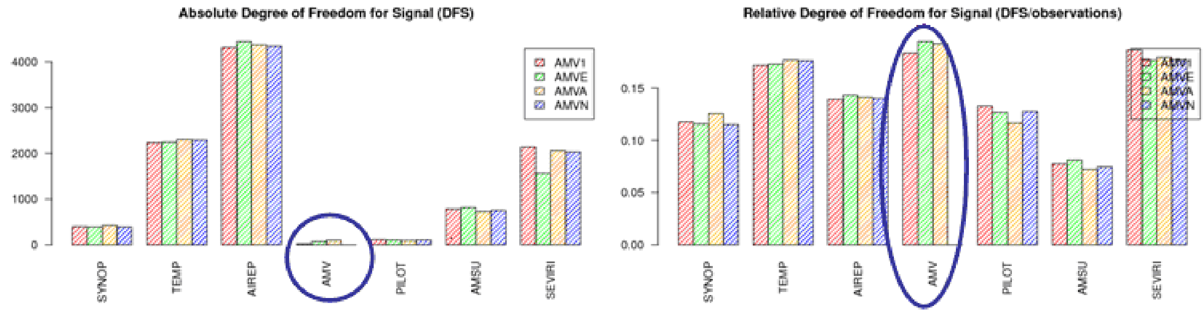


Figure 8: **Absolute and Relative impact (Degree of Freedom for Signal or DFS) for the different types of observations (including AMVs) in the NWP assimilation experiments at the Hungarian Meteorological Service. The red dataset is using the NWC SAF/HRW AMVs; the green dataset is using the EUMETSAT/MPEF AMVs; the yellow dataset is using both types of AMVs; the blue dataset is not using AMVs at all.**

Considering the NWP forecast, the inclusion of HRW AMVs causes:

- Small reductions in the mean RMSE of the surface pressure (specially in the second day, when they can be significant).
- Reductions in the mean RMSE of the precipitation.
- But also very small increases in the mean RMSE of the two metre temperature.

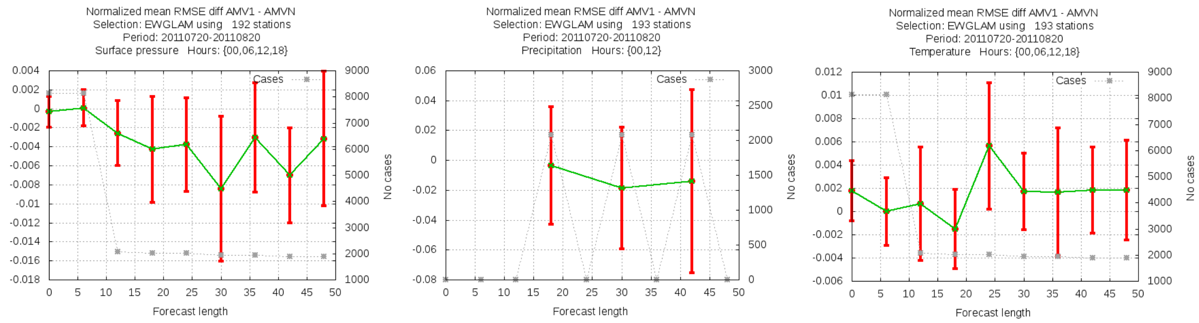


Figure 9: **Effect of the inclusion of the HRW AMVs in the NWP forecast, considering the Normalized mean RMSE difference respect to the experiment not using AMVs at all, for surface pressure (left), precipitation (centre) and two metre temperature (right).**

A complete report on these NWP Assimilation experiments has been prepared and is available at the NWC SAF Helpdesk (Randriamampianina, 2012, [RD.5]). Additional NWP assimilation studies are now under way at the United Kingdom Met Office and have also been shown at this 11th International Winds Workshop (Kelly, Cotton, Lean, García Pereda, 2012, [RD.6]).

STUDY ON "TEMPORAL AND SPATIAL SCALING ISSUES IN AMV EXTRACTION"

NWC SAF/High Resolution Winds product has additionally been used in an AMV Validation study, in collaboration with EUMETSAT, comparing AMVs with:

- Two different image scales (1 km SEVIRI/HRVIS and 3 km SEVIRI/VIS08 images).
- Two different NWP model scales (ECMWF model data with resolutions of 0.500º and 0.125º).
- The use or not of the NWP wind guess in the definition of the tracking area.
- Several different target sizes (8x8, 16x16, 24x24, 32x32 and 40x40 pixels).
- Several different temporal gaps between the initial and the later image (5, 10, 15, 20, 25, 30, 45, 60, 75 and 90 minutes).

AMVs have been calculated for a total of 150 different configurations in the "European and Mediterranean Region" defined in Figures 1 and 2, for the six month period January to June 2010, and validated comparing every day 1200Z AMVs with Radiosounding winds, NWP analysis winds at the AMV level, and NWP analysis winds at the best fit level.

The main conclusions of the study are:

- Good AMVs can be calculated with all these configurations (with a mean NRMSVD in all cases between 0.25 and 0.60).
- The use in the AMV algorithm of NWP data with different resolutions has no impact in the AMV output, causing insignificant changes in the values of the validation parameters.
- The validation statistics are better not using the wind guess for the definition of the search area, with a general small reduction in the NBIAS and NRMSVD, although also with a reduction in the amount of AMV data (which nevertheless is operatively not too significant in the cases operatively interesting).

AMV Validation (Jan-Jun 2010) with Radiosoundings 24x24 pixels / 15 min. time gap	HRVIS With wind guess 0.5º NWP	HRVIS With wind guess 0.125º NWP	HRVIS Without wind guess 0.125º NWP		VIS08 With wind guess 0.5º NWP	VIS08 With wind guess 0.125º NWP	VIS08 Without wind guess 0.125º NWP
NC	19874	19800	16254		15604	15520	14880
NBIAS (100-1000 hPa)	-0.105	-0.104	-0.098		-0.187	-0.186	-0.185
NRMSVD	0.381	0.380	0.374		0.475	0.473	0.466

Figure 10: **HRVIS and VIS08 AMV Validation statistics against Radiosounding winds, in the cases using a 24x24 pixel tracer size and a 15 minute temporal gap, respectively using wind guess with 0.500º NWP model data, using wind guess with 0.125º NWP model data, and not using wind guess with 0.125º NWP model data. (NC: Number of collocations; NBIAS: Normalized bias; NRMSVD: Normalized root mean square vector difference).**

Comparing the Validation statistics against the three different types of reference data:

- The NRMSVD is better in all cases (up to a 30% smaller) against the NWP analysis winds at the AMV level than against the Radiosounding winds. This shows a relatively worse agreement between the AMVs and the Radiosounding winds than against the NWP analysis winds.
- In the statistics against the NWP analysis winds at the best fit level, the NRMSVD reduces to values up to 0.08 (for HRVIS AMVs) and 0.11 (for VIS08 AMVs), while the NBIAS reduces to values up to -0.02 (for HRVIS AMVs) and -0.03 (for VIS08 AMVs). This verifies that the AMV errors can improve very significantly only through changes in the Height assignment process.

AMV Validation (Jan-Jun 2010) Running without wind guess and 0.125 NWP model data 24x24 pixels / 15 min. time gap	HRVIS against Radiosound.	HRVIS against NWP at AMV level	HRVIS against NWP at best fit level		VIS08 against Radiosound.	VIS08 against NWP at AMV level	VIS08 against NWP at best fit level
NBIAS (100-1000 hPa)	-0.098	-0.093	-0.021		-0.185	-0.160	-0.029
NRMSVD	0.374	0.254	0.091		0.466	0.345	0.120

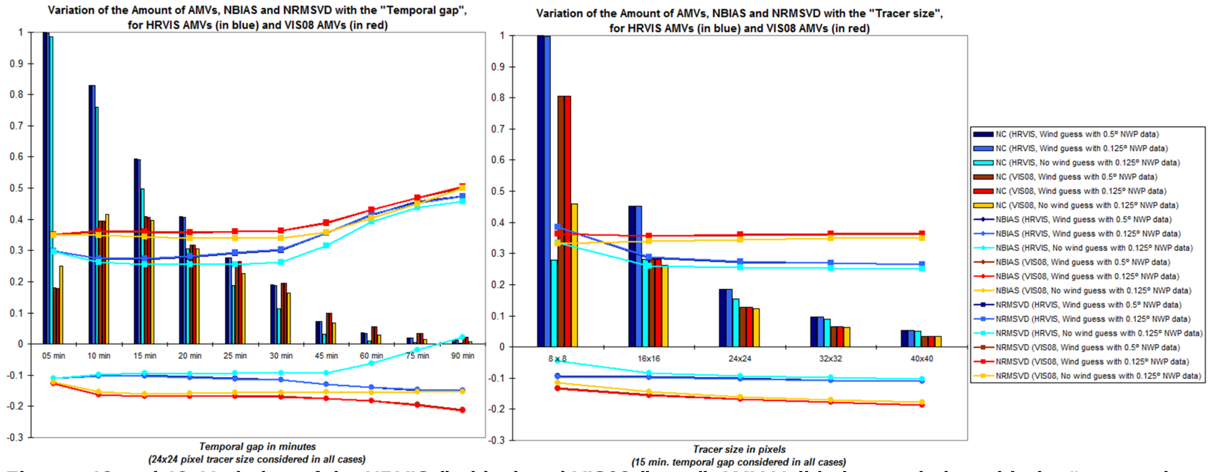
Figure 11: **HRVIS and VIS08 AMV Validation statistics against Radiosounding winds, NWP analysis winds at the AMV level and NWP analysis winds at the best fit level, in the case not using wind guess with a 24x24 pixel tracer size and a 15 minute temporal gap. (NBIAS: Normalized bias; NRMSVD: Normalized root mean square vector difference).**

Considering the “temporal gap between the initial and later images”:

- The maximum amount of AMVs is related to a temporal gap of 5 minutes for the HRVIS 1 km pixel scale, and between 10 and 15 minutes for the VIS08 3 km pixel scale.
- For temporal gaps up to 30 minutes, the impact of this parameter in the NBIAS and NRMSVD is very small. For longer temporal gaps up to 90 minutes, the NRMSVD increases progressively, but always keeping below 0.60. At the same time, the NBIAS becomes more negative with longer temporal gaps if the wind guess has been used, but not if the wind guess has not been used (becoming sometimes even positive).
- If both scales of pixels (1 km and 3 km) are considered together by the AMV algorithm, a “10 minute temporal gap” is considered as best option because of maximizing the amount of total AMVs while keeping very good NBIAS and NRMSVD values (due to the small variations in these validation parameters for all short temporal gaps).

Considering the “tracer size”:

- The maximum amount of AMVs occurs for 8x8 pixel tracer size for both HRVIS and VIS08 channels if the AMV algorithm tries to maximize the density of AMVs filling as much as possible the gaps in the image when finding tracers. But it has also been estimated that the maximum amount of AMVs occurs for tracer sizes between 16x16 and 24x24 pixels, when the tracers are extracted using a strict gridded structure (independent of the tracer size).
- The NRMSVD is smaller using larger tracer sizes (especially in the HRVIS cases), although for tracer of 16x16 km and over the impact of this parameter in the NRMSVD is very small. At the same time, the NBIAS becomes progressively more negative with larger tracer sizes.
- A tracer size of 16x16 pixels in the HRVIS case and 8x8 pixels in the VIS08 case maximizes the amount of AMVs keeping very good NBIAS and NRMSVD values experiments, if an AMV algorithm which maximizes the density of AMV data is used. A tracer size of 16x16 to 24x24 pixels seems instead the best configuration when the tracer extraction is defined using a strict gridded structure.



Figures 12 and 13: **Variation of the HRVIS (in blue) and VIS08 (in red) AMV Validation statistics with the “temporal gap between images while keeping a 24x24 pixel tracer size” (on the left) and the “tracer size while keeping a 15 minute temporal gap between images” (on the right), under the three possible configurations: using wind guess with 0.5º NWP data, using wind guess with 0.125º NWP data, and not using wind guess with 0.125º NWP data. (NC: Fraction of calculated AMVs respect to the maximum value of calculated AMVs; NBIAS: Normalized bias; NRMSVD: Normalized root mean square vector difference).**

The validation statistics against the Radiosounding winds and the NWP analysis winds at the AMV level show better results when using small tracer sizes (larger amount of valid AMVs, better NBIAS and the small impact on the NRMSVD). The smaller dispersion of cloud top heights in smaller tracer sizes ends to a better height assignment reducing the possibility of multilayer situations. The validation against the NWP analysis winds at the best fit level show better statistics using large tracer sizes.

It is important to note that larger variations occur in the absolute values of the BIAS and the RMSVD than in the normalized values of the NBIAS and NRMSVD in the different configurations, but these larger variations are caused by the important changes also occurring in the AMV mean speed, whose value in the different experiments can vary more than a 200%. Because of this, the analysis in this study has been based on the normalized statistics NBIAS and NRMSVD.

A final report of this study has been prepared (Garcia Pereda, 2012, [RD.7]). The study shall be extended to AMVs extracted from the SEVIRI/IR108 and SEVIRI/WV062 channels.

EVOLUTION OF NWC SAF/HIGH RESOLUTION WINDS

The "Satellite Application Facility on support to Nowcasting (NWC SAF)" starts now a new phase (CDOP2), which will last until 2017.

New developments for "High Resolution Winds product" during CDOP2 phase include:

- Its "use without wind guess" as default option through further algorithm optimizations (although this option is nevertheless already available in HRW v2012).
- Changes in the Quality control process, including the dependence of the Quality index threshold on the density of AMV data and the inclusion of the "Quality index without forecast" parameter.
- The extension of the AMV calculation to additional MSG/SEVIRI channels.
- The adaptation of HRW algorithm to additional Geostationary satellites (like the new NOAA/GOES-R and JMA/Himawari-8 series), after the adaptation of the NWC SAF/Cloud products.
- The use of HRW output in other NWC SAF applications (like the "Calculation of trajectories" and the "Extrapolation of Satellite and NWC SAF product images").

REFERENCES

NWC SAF Helpdesk, with general information on the "Satellite Application Facility on support to Nowcasting and Very short range forecasting", its software packages and products: www.nwcsaf.org.

Official documentation of the "NWC SAF/High Resolution Winds (HRW)" product (available at the NWC SAF Helpdesk at http://www.nwcsaf.org/indexScientificDocumentation.html):

[RD.1.] García Pereda J., 2012: "Algorithm Theoretical Basis Document for High Resolution Winds (HRW-PGE09 v3.2)". NWC SAF Document SAF/NWC/CDOP/INM/SCI/ATBD/09.

[RD.2.] García Pereda J., 2012: "Product User Manual for High Resolution Winds (HRW-PGE09 v3.2)". NWC SAF Document SAF/NWC/CDOP/INM/SCI/PUM/09.

[RD.3.] García Pereda J., 2012: "Validation Report for High Resolution Winds (HRW-PGE09 v3.2)". NWC SAF Document SAF/NWC/CDOP/INM/SCI/VR/10.

Description of "CCC Height assignment method":

[RD.4.] Borde R., R. Oyama: "A Direct Link between Feature Tracking and Height Assignment of Operational Atmospheric Motion Vectors', Proceeedings Ninth International Winds Workshop, Annapolis, USA, 2008.

Reports on the Assimilation of the "NWC SAF/High Resolution Winds (HRW)" output in NWP models:

[RD.5.] Randriamampianina R., 2012: "The impact of HRW on ALADIN/Hungary limited area model". Visiting Scientist Report at http://www.nwcsaf.org/HD/files/vsadoc/HRW_report_new.pdf.

[RD.6.] Kelly G., Cotton J., Lean P., García Pereda J.: "Application of the NWC SAF MSG/SEVIRI package to derive AMVs and their impact on the Met Office Nowcasting system". Proceedings Eleventh International Winds Workshop, Auckland, New Zealand, 2012.

Study on "Temporal and Spatial scaling issues in AMV extraction":

[RD.7.] García Pereda J., 2012: "Final Report on Temporal and Spatial Scaling issues in AMV extraction (v1.0, 27 April 2012)". Internal EUMETSAT Report.